DIMENSIONS NBS

The magazine of the National Bureau of Standards U.S. Department of Commerce

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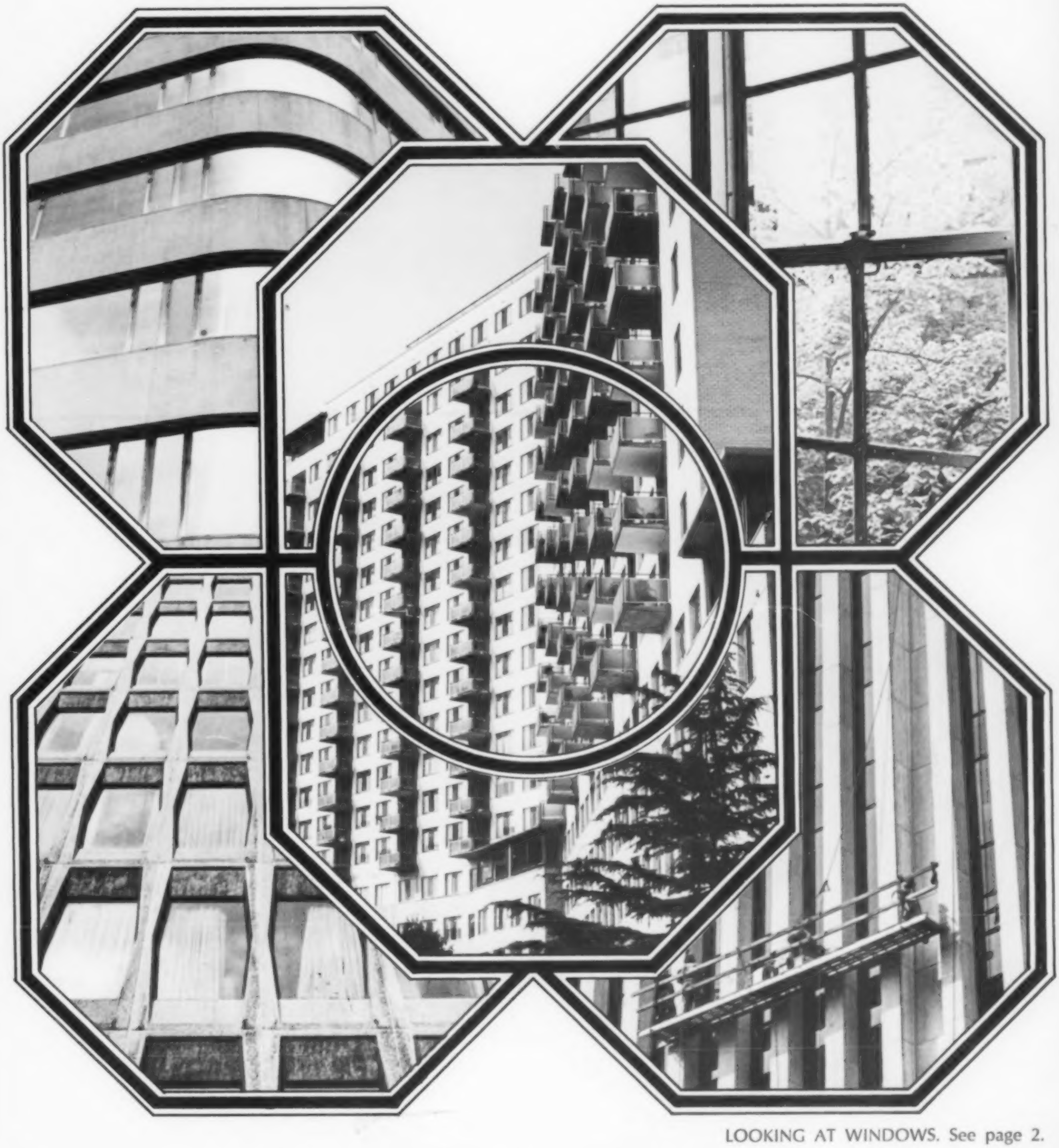

LOOKING AT WINDOWS. See page 2.

COMMENT

WHO'S IN CHARGE HERE?

Is measurement technology important to the National Bureau of Standards? To commerce and industry in the United States?

For the majority of us, the answer is a resounding YES! A mission in measurement technology was woven into the original enabling legislation of NBS. Measurement technology underpins the industrial superiority of the United States, especially in the high technology explosions going on now in electronics and other important sectors.

Much of our nation's strength in international trade derives from our advanced ability to measure and our sophisticated management systems which determine the strategic and tactical moves to exploit that technology. Our nation is the envy of much of the world.

This unique national measurement technology has grown up without anyone truly being in charge. A wide variety of driving forces really put the system in place—for example, legal requirements for equity in trade, economic requirements to improve productivity, technology breakthroughs which make possible the semiconductor revolution.

And now this *National Measurement System* baby has grown into a giant. Dr. R. D. Huntoon of NBS coined that term in the October 6, 1967, issue of *Science* magazine with an article entitled, *Concept of a National Measurement System*. His opening paragraph spells it out: "Concurrently with the growth and industrialization of this nation, there has developed within it a vast, complex system of measurement which has made possible the very growth that brought the system into being. This *National Measurement System* (NMS) stands today as one of the key elements in a worldwide measurement system that links all major nations together in a consistent, compatible network for communications and trade."

An exciting concept! Especially because the infrastructure of the NMS is so invisible and widespread, but still so important to our increasingly technological society.

In 1972 the Assistant Secretary of Commerce directed the preparation of a study of "The NBS Standards of Measurement to Determine if Their Accuracy is Sufficient for the Needs of U.S. Industry." This request led to initiation of a three-year study of the National Measurement System.

The study was a massive effort involving many people at NBS in all divisions of the Institute for Basic Standards. The result is an equally massive series of reports which constitute an impressive "snapshot" of a very complex and pervasive system. This system underpins the technological-economic structure of our country and its relation to the world.

But in this great size and strength is also a great weakness. *No one is in charge!* The NMS is without direction. And that causes me serious concern. Six percent of our gross national product is involved with measurement. Larger percentages of our high technology science and industry sectors are even more crucially dependent on NMS.

In my opinion, the National Bureau of Standards should be assigned responsibility as the National Measurement Science Center, with the duty to further refine the present status of NMS, define future directions, and provide the management impetus for a national commitment to keep our nation's science, technology, and industry in a leadership position.

This isn't going to be easy. There are sentiments in our population and Congress that science has gone wrong; technology has messed up our lives.

But we of the scientific and industrial community who can understand the implications need to make ourselves heard. The National Conference of Standards Laboratories will be working for a national commitment to meet national needs.

John L. Minck
Immediate Past President
National Conference of
Standards Laboratories

In October Minck completed his year as President of the NCSL. NCSL is an association of 295 companies and organizations which maintain or have an interest in measurement standards and calibration facilities. Minck is an executive in the Stanford Park Division of the Hewlett-Packard Company. He has been active in measurements for most of his 19 years with HP.

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MAKING THE MOST OF WINDOWS

by Juli Kelley and David Chaffee

COVER STORY

WHAT is it worth to your family and how much does it cost to have rooms with a view—simple windows, that is—in your home, your children's school, or the local hospital?

If you want to answer intelligently, you have to consider a number of factors, such as the psychological effects of having or not having a view, what windows mean in terms of the energy a building requires, and how much they cost to install and maintain.

More than two years ago, a research psychologist at the National Bureau of Standards, Belinda Collins, surveyed the technical literature concerning the psychological effects of windows on people.* Her search disclosed a number of findings that emphasize the importance of windows to the overall well-being of people. One report, for instance, showed a positive relationship between the presence of windows and patient recovery in hospital intensive care units.

If windows are necessary to satisfy certain aesthetic and psychological needs, the aim of any frugal building designer, owner, or operator—from the federal government to the homeowner—is this: to maximize the positive effects (or *performance*) of windows so that all possible benefits are captured.

For over two years, a team of NBS scientists and engineers headed by Collins has been studying ways of achieving this goal. The program has been funded by several government agencies ** and involves work in a number of disciplines: architecture, economics, psychology, and mechanical engineering. Individual projects have included an analysis of how windows can affect energy use through thermal performance and illumination, an assessment of the cost-effectiveness of windows over a 25-year period (called life-cycle costing), and a determination of design strategies for energy conservation.

In one study, Collins and mechanical engineer Tamami Kusuda collaborated to calculate some of the energy requirements associated with three different modes of window design and management *** Kusuda developed a computer model incorporating these strategies, and the researchers applied the model to a hypothetical room in a building in Washington, D.C.

First, a window was treated as a bare piece of glass. Second, window management was added in the form of thermal shutters on winter nights and venetian blinds on summer days. Third, calculations were made of the effects of substituting daylight for electric lighting whenever practical.

For each mode, the researchers compared the thermal effects of a number of window areas with those of a solid wall. Further, windows were studied in four orientations—north, south, east, and west. In each orientation, calculations were made for one, two, and three layers of glass (single, double, and triple glazing).

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Kelley is editor of DIMENSIONS/NBS. Chaffee is a DIMENSIONS staff writer. This article is based on research conducted in the NBS Center for Building Technology, Institute for Applied Technology.

*See NBS-BSS 70, *Windows and People*, June 1975. See also DIMENSIONS/NBS August 1975 for a discussion of Collins study.

** The National Bureau of Standards, the Energy Research & Development Administration (now the Department of Energy), and the Department of Housing and Urban Development have provided funding for this project.

*** Their report, BSS 109, *Simplified Analysis of Thermal and Lighting Characteristics of Windows*, is in press.

Based on the model, the use of double glazing cut the average seasonal heating requirement in half. The computer calculations also showed that placing a window in a room with a southern exposure and double glazing it made that room almost as energy-efficient as one with solid walls. When the researchers substituted daylighting for electric lights, calculations showed that certain window areas made the room more energy-efficient than the same environment without a window.

In conducting a related study, economists Rosalie Ruegg and Robert Chapman incorporated the results of Kusuda's computer model into a model of their own, one developed for the purpose of conducting life-cycle costing analyses. Their model takes into account the present and future costs of energy over a 25-year period and the costs of acquiring, maintaining, and repairing a window over the 25-year "life cycle."

Ruegg and Chapman used the model to determine the cost-effectiveness for new buildings of alternative window designs, sizes, accessories, and orientations. They analyzed residences and commercial buildings located in nine U.S. cities representative of five major heating zones and four major cooling zones in the United States.

For maximum reduction in cost and energy use, daylight should be used to supplement or replace electric lighting.

Their study adds a new dimension to the work performed by Kusuda and Collins. By taking a life-cycle approach and including costs other than energy, the economists were able to determine which energy-conserving designs and accessories are the most cost-effective to incorporate when a building is being constructed.

For example, double glazing will usually result in reduced energy consumption. But under certain circumstances the reduction will not be enough to recover the cost of the double glazing, even with escalating fuel prices over time.* In the Washington, D.C., area, however, Ruegg and Chapman found that it was generally cheaper to have a window double glazed or managed (equipped with energy-saving accessories such as venetian blinds) than to have it single glazed and bare.

The life-cycle cost analysis reinforced one of the central findings of the Collins-Kusuda study: the economists found that when daylight was used to supplement or replace electric lighting, it was cheaper to have a window, even a large one, than

* With buildings already in existence, which were not designed to optimize window performance, the addition of double glazing in the form of storm windows is highly energy efficient and cost effective.

Use Windows Wisely

- Place trees, shrubs, or a fence opposite a window. They slow down the wind that comes into contact with the window. The result can be reduced air infiltration through cracks, reduced cooling of the window glass, and partial protection from the summer sun (particularly with west-facing windows).
- Use interior accessories such as venetian blinds, draperies, shades, or shutters to best advantage. Closing these accessories when the window is sunlit in summer reflects much of the sunlight back out the window before it can overheat the room. Opening them on sunny winter days allows the sunshine to help to heat the room. Closing them at night during the winter can create a partial insulating air pocket, reducing heat loss and improving comfort near windows.
- Consider exterior devices. Awnings installed in the summertime, for example, block sunlight outside the window where any heat build-up can be dissipated to the outside air before it ever enters the room. They also reduce glare and provide protection from rain.
- Weatherstrip around windows. This reduces the infiltration of outside air, eliminates uncomfortable drafts, and improves sound insulation.
- Turn off electric lights whenever daylight can provide sufficient illumination.
- Before building a house, consider the effects of window orientation. South-facing windows can take advantage of the winter sun to reduce heating requirements. In cold climates, minimize north-facing window areas.
- Add storm windows,* particularly with triple-track kind, which can be used both during heating and air conditioning periods and can be opened for natural ventilation at other times. A recent NBS study showed that they can save up to 20 percent or more energy during the winter. They should be properly installed and fit tightly for maximum benefit. To assure a tight fit, permanent storm windows should be sealed to the outer window frame with caulking compound or other sealing material. Storm window frames should have a tiny opening at the bottom to allow water vapor to escape.

* This recommendation is based on an NBS study of methods of conserving energy in an older home. The results of that research will be discussed in the next issue of DIMENSION/NBS.

Discussing a report are window project members (clockwise from left) Belinda Collins, Robert Chapman, Tamami Kusuda, Robert Hastings, and Rosalie Ruegg.

to have a windowless room. (Windows ranging in size from small to medium were the most cost-effective.) However, if a window—no matter how small—was not used for daylighting, it raised the life-cycle cost of a building, according to Ruegg and Chapman's Washington, D.C., case study.

Based on that study, the economists say that the extra energy costs—incurred when daylight is not used for illumination—can be greatly reduced by combining the following three practices: using small windows, placing them on a south wall, and equipping them with shading and insulating accessories such as thermal shutters or using double glazing.

If east- or west-facing windows are used, money can still be saved with either double glazing or accessories. It is especially important for large windows in any of those three orientations to double glaze or use accessories. With a window of any size facing north, it pays to exercise both options: insulating accessories *and* double glazing.

Still other opportunities exist for improving the performance of windows, and architects S. Robert Hastings and Richard Crenshaw have explored the numerous design options that are available. Their findings, which were used in part in the computer modeling studies, are discussed in a report called *Window Design Strategies to Conserve Energy*.* Hastings and Crenshaw explain the options—from sunscreens to landscaping—and how they work to improve window performance.

For example, shrubs near a window can reduce the force of the wind before it reaches the window. This decreases air leakage through joints and reduces the cooling effect of the wind against the glass. Deciduous trees can also improve the energy efficiency of a window. In winter, their bare branches allow sunlight to penetrate through to the glass; yet their leaves block unwanted sunlight in the summer.

Awnings are often put up outside a window in the summertime to provide shade and still allow a breeze to circulate. Devices outside the window are the most effective in regulating unwanted summer sun. Included are sun screens, roll blinds, architectural projections, and shutters.

Hastings and Crenshaw also discuss how various internal accessories can permit energy flow through windows to be managed. Venetian blinds can reflect summer sun to the outside or direct daylight to the ceiling for deeper light penetration. Thermal shutters can be closed at night to reduce heat loss in winter.

The real worth of a window, like beauty, may be in the eye of the beholder. But the research efforts at the National Bureau of Standards are aimed at maximizing window performance through considerations such as energy efficiency, life-cycle costs, and psychological needs. □

*NBS-BSS 104, available from the Superintendent of Documents, U.S. Government Printing Office for $3.75. Order by stock number 003-003-01794.

TOWARD A National Environmental Monitoring System

Measurement is a Key

PRESIDENT Carter's Environmental Message of 1977 directed the Council on Environmental Quality to establish an Interagency Task Force to review present environmental monitoring and data programs and to recommend improvements to them. Baseline monitoring is especially important so that environmental changes posing hazards to health and welfare can be discovered as they begin.

To be able to detect these changes early requires establishing a national reference baseline network for selected pollutants which are indicators of environmental quality in air, water, soil, and biological specimens. In addition, baseline data also serve to indicate and project trends in environmental quality—a measure of the effectiveness of our efforts to reduce pollution.

Recognizing that there are major deficiencies in all existing environmental monitoring programs, the Subcommittee on the Environment and the Atmosphere of the House Committee on Science and Technology recently held hearings to investigate the feasibility and practicality of developing and implementing a prototype monitoring system. This might eventually be expanded into a comprehensive national or international program. NBS was asked by the subcommittee to explain how one can insure that measurements made in a national environmental monitoring system are intercomparable. The following article is the Bureau's response.

by J. Paul Cali

THE need for man to know the current status and possible future condition of the environment is of unquestioned importance. In addition, to be able to predict with high probability how man's activities, both present and future, will impact on our environment is equally critical. We can only acquire this knowledge through the process of environmental monitoring, a process involving the systematic measurement of environmentally important parameters, such as the ozone concentration or levels of sulfur dioxide in the atmosphere.

Although measurements are central to this process, to date, some environmental monitoring system have not taken full advantage of procedures available to insure reliability in advanced measurement systems. Reliability in measurement is important to insure that environmental data can be compared on a common basis over long periods of

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NBS Standard Reference Materials are used to calibrate equipment involved in measuring automotive emissions.

time, that data gathered in different places are comparable, and that sufficient sensitivity can be built into the system to show small but, possibly, significant changes, for example, to indicate carbon dioxide build-up or depletion.

Measurement and Measurement Capability

By measurement, I mean that process whereby a number, on some agreed upon scale, is determined to indicate the magnitude or degree present of a specific property of a material being evaluated.

Man measures the properties of materials for many diverse purposes: the testing of a scientific theory; the assurance of a uniform or sufficient quality of a manufactured product; the regulation of environmental quality, and many others. Indeed, measurement lies at the heart of all technologically based societies. A key point is that measurements are rarely made in isolation; at least two parties are usually involved. In the three examples just cited the two parties are: the theoretician and experimentalist; the quality control manager and the production engineer; the regulator and those regulated. Thus, measurement is basically a means of communication for some useful end purpose.

If this communication is to be effective, the measurements must be made in a consistent and reliable way so that they are compatible. A measurement system is said to be compatible when two or more measurements made independently on an identical, stable material produce measurement values that agree within some predetermined and agreed on limits of uncertainty. These limits of uncertainty are inherent in the nature of our physical world and, though controllable to a degree, cannot be entirely eliminated. The limits to the uncertainty must take into account the purposes for which the measurements are being made. For example, measuring properties to an accuracy greater than needed for the end purpose is both unnecessarily expensive and often technically frustrating.

Compatible measurement networks on a national scale do exist today. Many different modes are used to achieve compatibility, for example, the accurate dissemination of time to commercial users and the general public. Time measurements are made by the U.S. Naval Observatory and the National Bureau of Standards. The integration of these measurements is then made with those in foreign countries. Finally, these time signals are provided to these users by the NBS radio station, WWV, in Boulder, Colorado. Thus, compatibility of time measurements is assured because all users accept and use this network as their reference point. Similarly, the measurement of mass for buyer-seller transactions is hardly ever called into question, because weights traceable through NBS to the world's primary standard are readily available to calibrate or verify our commercial scales, thus assuring compatibility over both time and geographical location.

There is too much "trust" in the instrumentation used to gather data.

The achievement of compatible measurements for the property called chemical composition, the property of prime importance in most environmental monitoring considerations, is not as straightforward as those for time and mass. Why? Because there is no one single device or mechanism whereby measurement compatibility for the property, chemical composition, can be assured.

To understand how compatibility may be achieved for measurements involving chemical composition, we first need to discuss a concept called accurate measurement. Every property of a specific, homogeneous, stable material has a number on some scale that is its actual value. This value is often called the "true value." It is, at least intuitively, evident that at one point in time there must be

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Among the Standard Reference Materials that NBS offers for environmental research is Trace Elements in Spinach, shown here. The standard is used to calibrate instruments that test for toxic substances present in minute quantities in the Food and Drug Administration's sample "market basket" survey of fruits and vegetables.

only one unique "true value" of the property for this material. Thus, if one can design the measurement network so that each measurement station always obtains the "true value," then, because there can be only one "true value," all laboratories within such a network must obtain identical results. This is, of course, our meaning of measurement compatibility.

Accurate measurement systems are designed so that "true values" are obtained. An accurate measurement is one both precise and free of systematic errors. Systematic errors are those errors that make the measurement deviate from the "true value" no matter how precise, (i.e., reproducible). Because systematic errors mislead judgment, they must be eliminated or corrected. Precision is a measure of how well measurements can be reproduced, i.e., how well the same measurement value can be obtained when the measurements are repeated. Without high precision the finding and elimination of systematic errors is difficult—often impossible.

An Approach To Accurate Measurement

The development of an accurate measurement system may proceed from first principles, but this is a long, slow, costly process. For a nationwide system of the type required for environmental monitoring, the need for a procedure to bypass this approach is self-evident. Fortunately, such an approach is feasible and does already exist in many fields.

Three ingredients are necessary for proper functioning of this system: an agreed-on system of measurement units, so that all measurements are reported on the same scale; a well-characterized material whose properties have been accurately assessed, to allow calibration of measuring instruments or the testing of measurement methods; and a reference method of demonstrated accuracy, in order to assure that no sources of systematic error are introduced in the measurement process.

These three ingredients will provide reliable environmental data. In addition, mechanisms to assure the long-term integrity of the measurement process must be incorporated into such a system. Not only will data be comparable on a short-term, local basis, but also data so gathered will be compatible over long time spans and over long distances.

A sufficient supply of these three ingredients is now available, so that a prototype monitoring system utilizing this approach can be demonstrated. First, there is general agreement on measurement units, which basically are reported in the SI (or more popularly, metric) system of units. Second, a wide-range of well-characterized reference materials is becoming available. NBS alone has developed more than 80 Standard Reference Materials (SRM) for use in environmental analysis. Because the chemical composition of these SRM's is known with high accuracy, they can be used to calibrate or check instrument performance. Many other reference materials are in the research stages. Reference samples are also available from the U.S. Environmental Protection Agency, and, under special circumstances, from the U.S. Geological Survey. Third, a wide variety of tested and reliable methods of measurements is also becoming available for use. Many of these methods have been developed by EPA and standards bodies such as the American Society for Testing and Materials.

There are, of course, many gaps yet to be filled, for both reference materials and reference methods. For example, reference materials and methods for trace organic constituent analysis are still lacking. Nevertheless, sufficient reference materials of the highest quality and well-tested reference methods exist for many environmental constituents, so that

Albert E. Ledford is shown with a new NBS-developed instrument used to measure very small amounts of ozone, a serious air pollutant at ground level. The instrument is the only one of its kind in the United States, and scientists from around the country have used it to calibrate their ozone measuring instruments.

a prototype national environmental monitoring network based on accurate measurement principles could be demonstrated today.

Such a demonstration, taking into account all the factors mentioned, has not yet been accomplished on a national scale. There are several reasons for this state of affairs:

- There is a tacit assumption that each and every scientist involved has had formal training in and understands measurement principles. Unfortunately, this is not the case today. Measurement science as such is not taught as a subject in its own right in today's college curricula. Further, it is assumed that measurement scientists and, in particular, measurement technicians, are well-versed in the techniques of accurate measurement. This, too, is a false assumption. Many scientists today can perform complex calculations and discuss complex theory, but have not been trained in techniques for calibrating their basic measurement tools: balances, volumetric glassware, burets, etc.
- The designers and managers of many environmental measurement networks are not trained as analytical chemists, but rather as systems engineers, data processors and analysts, physicians, etc. Yet in most environmental networks, the property to be measured is that of chemical composition, requiring the involvement of the analytical chemist at every stage of planning and implementation.
- There is a misplaced emphasis on data gathering, data reduction, and data analysis without the sufficient awareness that unless the measurement values are accurate (and thus reliable) the computer adage "garbage in, garbage out," is likely to be only too true.
- There is too much "trust" in the instrumentation used to gather the data, i.e., to make the measurements. Many instruments used today in environmental monitoring are highly sophisticated and automated. This may give a false sense of security to the analyst, lulling him into believing that expensive and elaborate equipment must produce reliable data. Although such systems may often produce highly reproducible results, they do not necessarily produce accurate results. Moreover, the high precision often gives an illusion of high accuracy.

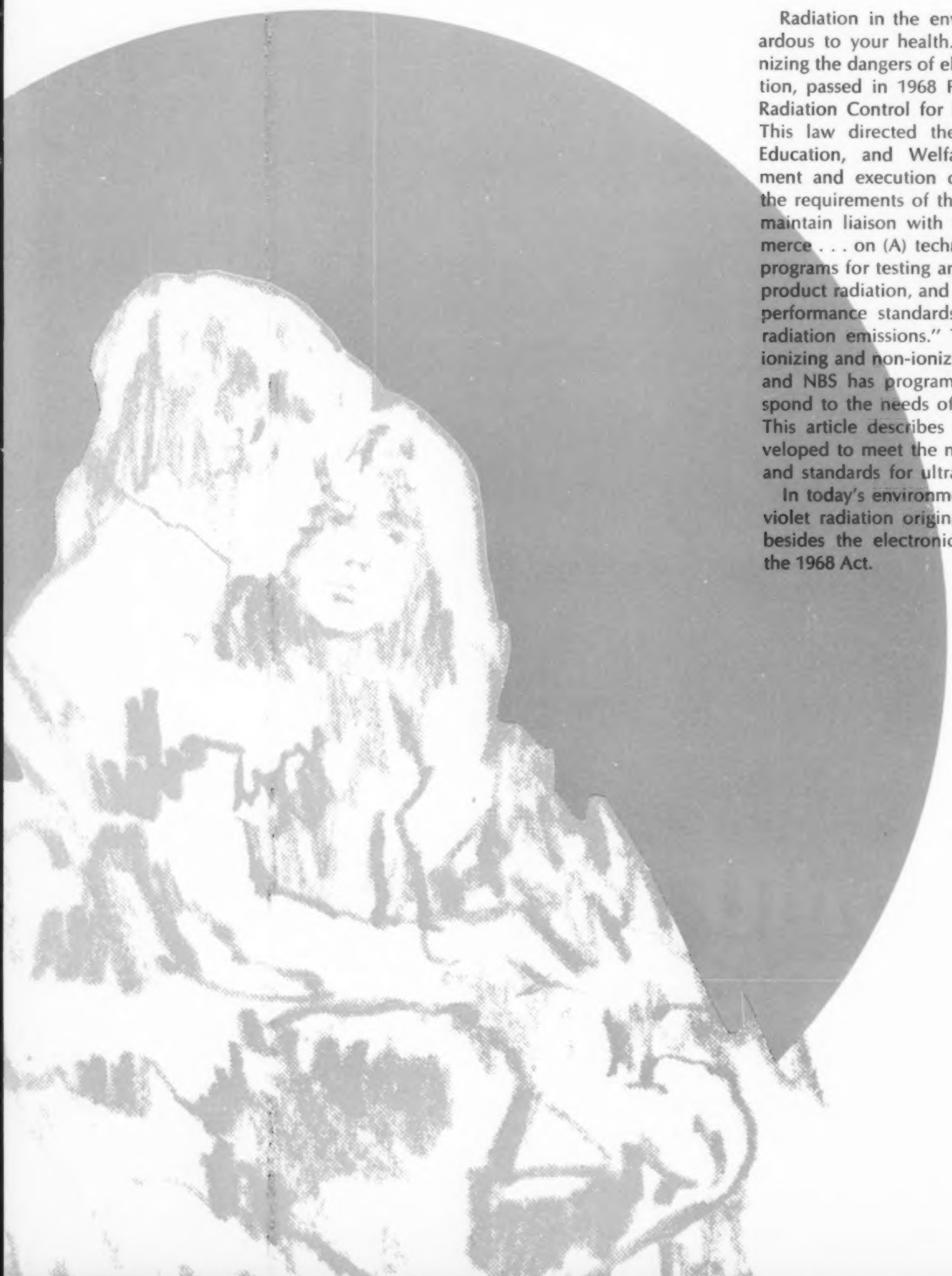
A number of steps should be considered in overcoming these obstacles. First, the question of accurate measurement must be explicitly addressed in the design of a prototype environmental monitoring system. Each and every measurement datum should be accompanied by a statement of its uncertainty. Limits of uncertainty include estimates both of bias and measured precision. In addition, formal training sessions involving managers and participants should be instituted *before* the actual work is undertaken. This training should include: the concept of measurement compatibility, how it is achieved, concepts of accuracy and precision, systematic error identification and analysis, etc.; the development and use of training manuals and laboratory experiments; discussions and instructions on data gathering, reduction and reporting of data.

A monitoring system based on the accurate measurement principle will provide a rational, consistent, and reliable basis for regulation.

After training, a program should be established to assure, through routine testing of the laboratory, that individual laboratory performance of each participant achieves some minimum quality level. Lastly, the tools required for accurate measurement must be provided, including agreed upon units of measurement, well-characterized reference material, reference methods of demonstrated accuracy.

If these recommendations can be implemented, then the chances for a successful demonstration of a prototype monitoring system for the environment will be increased considerably. Further, a monitoring system based on the accurate measurement principle will provide a rational, consistent, and reliable basis for regulation where this is required. □

Ultraviolet Radiation Standards



Radiation in the environment can be hazardous to your health. The Congress, recognizing the dangers of electronic product radiation, passed in 1968 Public Law 90-602, the Radiation Control for Health and Safety Act. This law directed the Secretary of Health, Education, and Welfare, in the establishment and execution of a program to meet the requirements of this Act, to "consult and maintain liaison with the Secretary of Commerce . . . on (A) techniques, equipment, and programs for testing and evaluating electronic product radiation, and (B) the development of performance standards . . . to control such radiation emissions." This Act includes both ionizing and non-ionizing radiation emissions, and NBS has programs in both areas to respond to the needs of the Secretary of HEW. This article describes the NBS programs developed to meet the needs for measurements and standards for ultraviolet radiation.

In today's environment, hazards from ultraviolet radiation originate from many sources besides the electronic products specified in the 1968 Act.

for Health and Safety

by Lucy Hagan

LIFE-SUPPORTING sunshine can threaten the very life it sustains if crops, animals, and people are overexposed to the sun's ultraviolet rays. Similarly, ultraviolet (UV) radiation from artificial sources used in health care and industry carries the potential for harm as well as for benefit.

To complicate matters, solar UV radiation may be increasing at the earth's surface as a result of the depletion of the ozone layer in the atmosphere—the layer that normally absorbs most of these rays. One theory is that chemicals, primarily halocarbons from aerosols and refrigerants, are causing this phenomenon. Of course, a natural variability in the spectral distribution of solar radiation may also affect the amount of ultraviolet radiation that strikes the earth's surface. The simple fact is that until we can measure the amount of UV radiation in the environment with greater assurance of accuracy—whether in the clinical laboratory, the industrial workplace, or the outdoors—we will have to grapple with serious uncertainties.

The National Bureau of Standards is responding to a national need by providing the ultraviolet radiation measurement standards required for environmental safety and health. Major NBS programs are directed toward this purpose.

SURF

A major NBS facility, the Synchrotron Ultraviolet Radiation Facility (SURF) is dedicated solely for use as a source of ultraviolet radiation. The group at NBS led by R. P. Madden was the first to develop an electron synchrotron facility for study of ultraviolet radiation and its effects on matter. SURF now consists of a new electron storage ring with the associated beam lines and spectrometers. It operates at electron energies up to 250 MeV, electron currents over 20 mA and lifetimes as long as 6 h. The performance of the ring has exceeded all of its design specifications. A National Academy of Sciences report projects that the need for extreme-ultraviolet synchroton radiation facilities will increase within the next ten years to a minimum of 480 users. In response, NBS has made its dedicated facility available to users in the general scientific community outside NBS.

Synchrotron radiation is particularly suited for radiometry since it is a smooth continuum covering a wide spectral range. The amount of radiation emitted at a given wavelength in a given direction may be calculated from classical electromagnetic theory. The radiation emitted by SURF is determined by measuring the values of certain parameters of the orbiting electrons in the storage ring. The number of orbiting electrons, their energy, and the radius of curvature of their orbit are determined experimentally. SURF is designed to allow these parameters to be determined quite accurately. The electron energy is calculated from the measured value of the magnetic field. The radius is determined from the value of the radio frequency of the cavity. The orbiting current is determined from radiometry on the light emitted by SURF in a known bandwidth in the visible spectral region.

Optical prisms shown here are used to refract the incoming laser beam into its component beams of different wavelengths, for use in the facility for characterizing silicon photodetectors.

NBS is responding to a national need by providing the ultraviolet radiation measurement standards required for environmental safety and health.

Radiometric Calibrations

SURF is a unique facility for radiometric calibrations in the extreme-ultraviolet spectral region. It has been used as an absolute irradiance source for calibrations of spectrometers and photometers. Measurements of the absolute irradiance in the extreme ultraviolet region can be determined to an accuracy of better than 5 percent in the wavelength range 4 nm to 400 nm.

With SURF as a UV source, radiometric detector calibrations can be made from 5 nm to 60 nm with accuracies better than 10 percent. By using laboratory UV sources, the NBS calibration range for far ultraviolet and ultraviolet transfer standard detectors extends up to 320 nm with accuracies of approximately 10 percent, thus filling the gap between x-ray radiometry and visible-near ultraviolet radiometry. This capability enables radiometric meas-

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Dr. Hagan is scientific assistant to the director of the NBS Institute for Basic Standards.

urements to be made over an extremely wide spectral range by users studying the diagnostics of controlled thermonuclear reactor (CTR) type plasmas, upper atmosphere and solar physics, and health and safety monitoring.

Plasma Sources

In the Plasma Spectroscopy Section, W. L. Wiese and his group have developed the NBS hydrogen arc. This is an independent primary standard of spectral radiance, since the hydrogen continuum emission coefficient is calculable to a very high accuracy. This dc high power hydrogen wall-stabilized arc may be used in the wavelength range 125 to 360 nm (overlapping the range for use of the conventional tungsten strip lamp for radiometry) with estimated uncertainties of 5 to 10 percent depending upon wavelength.

The radiation emitted by this dense plasma discharge is observed end-on. The hydrogen arc is operated at temperatures of about 20 000 K where the continuum emission coefficient reaches a broad and unique maximum, which is readily observed. The main emphasis of the plasma source radiometry program is to provide convenient portable UV transfer standards which can be readily applied by the user in his own laboratory. This requires the development of special transfer standards, since the hydrogen arc, because of its high power requirements and complexity, is restricted to use in performing calibrations at the NBS laboratory.

The researchers have thus developed and characterized several easily operable secondary standards. Initially, commercial deuterium lamps (D_2 lamps) were developed and utilized and numerous lamps were calibrated against the hydrogen arc as secondary or transfer standards for use in the wavelength range 165 nm to 350 nm. To extend the limited wavelength range and to eliminate aging effects of the deuterium lamps, the argon "mini-arc" has recently been developed. The mini-arc has an extended wavelength range from 115 to 330 nm and does not exhibit aging effects, that is, changes in intensity emitted from the lamp as a result of prolonged use. About a dozen argon mini-arc sources are now in use at other laboratories for UV radiance calibrations.

To fulfill a need for a standard source of greater intensity, a higher powered argon arc, the "maxi-arc," has been developed and tested. All of these transfer sources, the deuterium lamp, the mini- and maxi-arcs, are useful as standard sources of radiance or irradiance. They each provide a steady-state continuum spectrum.

The deuterium lamp is a small, low-powered (30 watts), low-pressure, sealed arc lamp. The lamp is easy to use, although for radiance calibrations the alignment is critical. The lamps should be used only for brief periods as calibration sources, since the emitted level of radiation may change significantly over long use. From NBS, radiance calibrations are available for 165-350 nm with a 10 percent uncertainty, and at present, irradiance calibrations are available in the range 200-350 nm with a 6 percent uncertainty.

The argon mini-arc is a well-stabilized arc discharge operated in argon at one atmosphere pressure with a continuous flow of gas through the arc. The emission from the arc is uniform over a solid angle, allowing calibrations with fairly large aperture beams. The sensitivity of the mini-arc radiance to changes in various operating conditions, including current, argon flow rate, and pressure, has been measured.

The uncertainty in the spectral radiance of a calibrated arc is estimated to be 6 percent for wavelengths greater than 140 nm and 11 percent for wavelengths in the range 115 to 140 nm. Calibrations of irradiance from the mini-arc over this wavelength range are in progress. Since it is an inhomogeneous source, the irradiance has a variation with wavelength slightly different from the radiance.

To provide a more intense source for radiance and irradiance calibrations a higher powered argon arc, the maxi-arc, has recently been developed. A prototype has been operated at 7 kW. At this power, the irradiance is about 18 times that provided by the mini-arc. The spectrum of the maxi-arc and its wavelength range are similar to those of the mini-arc.

Tungsten Strip Lamps

Calibrated tungsten strip lamps were developed by NBS to meet the requirements of the U.S. space program for more accurate and convenient source-based radiometry. These lamps, used as radiance standards from 250 nm to 2.6 μm, were introduced in 1960 with uncertainties of 8 percent to 3 percent over this wavelength range. In 1963 coiled tungsten filament lamps calibrated for radiant power in the same wavelength range were introduced as irradi-

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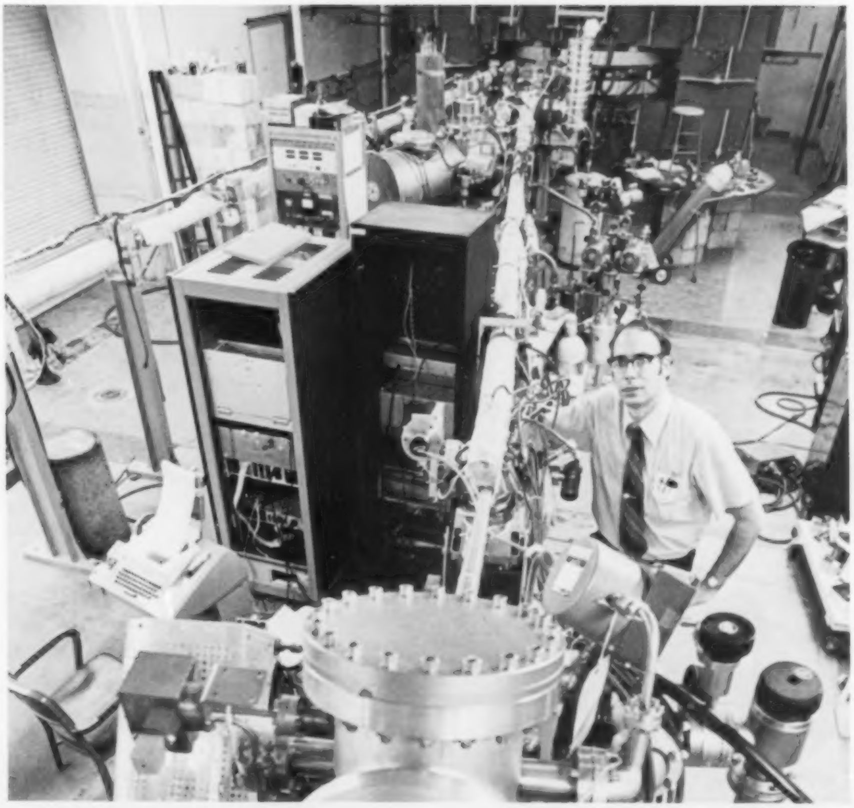
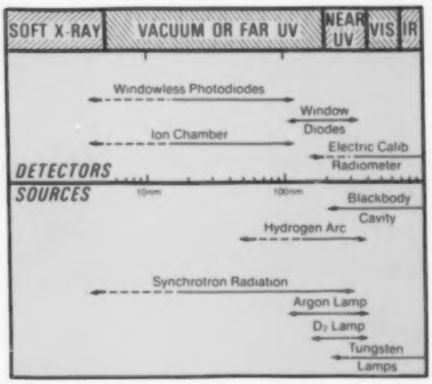


Dr. Edward B. Saloman is shown at the SURF calibration facility. Radiation from the SURF storage ring is used to calibrate radiometric detectors which are placed in the vacuum chamber (foreground). Calibration can be made from 5 nm to 60 nm with accuracies better than 10 percent.



Current and projected NBS standard source and detector capabilities. The dashed lines indicate near term projections.

Physicist James H. Walker is shown calibrating the 20-watt special fluorescent lamp (right) to be used for the UV-B spectral region (280 to 320 nm). The skin is extremely sensitive to ultraviolet radiation in this spectral region. The lamp on the left is the tungsten-filament quartz-halogen lamp which is being used as the reference irradiance standard.

ance standards with similar uncertainties. During the past ten years, Dr. H. J. Kostkowski and his Optical Radiation group have improved the accuracy of these standards to about one percent in the visible and infrared and about two percent in the UV wavelength regions. The calibrated tungsten ribbon filament lamp sources are currently available as spectral radiance standards in the range 225 nm to 2400 nm. The coiled tungsten filament lamp, called the quartz-halogen lamp because a quartz envelope contains a halogen gas filler around the filament, is operated at 1000 watts to obtain maximum intensity and is calibrated in the 250-to 1600-nm range as a spectral irradiance standard.

Typical spectral irradiances of the available calibrated sources in the UV-B region (280 to 320 nm), where the skin is most sensitive to ultraviolet radiation, are summarized in table 1 and compared to the terrestrial solar irradiance.

To meet the growing need for standardization in the UV-B spectral region, the Optical Radiation group will soon make available a 20-watt special fluorescent lamp calibrated for spectral irradiance. These new lamps will be mechanically interchangeable with the presently available tungsten-filament, quartz-halogen spectral irradiance standards which are usually recommended in this spectral region. They will provide a useful and convenient diagnostic tool for assessing the performance of spectroradiometers, used in the UV-B spectral region. It is expected that the uncertainty in the relative spectrum will be 2 to 3 percent and the absolute uncertainty 5 to 6 percent.

Significant improvement in laboratory UV measurements requires more accurate and stable spectral irradiance standards.

The major factors that influence the uncertainty of UV spectral measurements are the measuring instrument, the standard, the measurement technique, the character of the radiation and the conditions under which the measurements are made. H. J. Kostkowski recently completed a detailed analysis of these uncertainties. He concluded that the best spectral irradiance measurements that can be made today between 250 and 350 nm have uncertainties ranging from about 3 percent for highly controlled laboratory measurements of a simple character to about 25 percent for measurements of very complex radiation under favorable field conditions. When state-of-the-art techniques are not used, the uncertainties are even larger.

Spectroradiometers

During the past year, NBS scientists investigated and characterized several of the currently available spectroradiometers that are most suitable for UV measurements. The conclusions of this study, reported in the April 1977 issue of NBS Optical Radiation News, are summarized below.

Currently, the easiest and only practical way to calibrate a spectroradiometer is by using a standard source. In the wavelength region from 250 nm to 350 nm, the most accurate standard source for spectral irradiance, and the one usually recommended, is the 1000-watt tungsten-filament, quartz-halogen lamp. Those issued by NBS have an uncertainty ranging from 2.6 percent at 250 nm to 1.7 percent at 350 nm. The imprecision of calibrating the best spectroradiometers in this wavelength region with such a tungsten standard is only a few tenths of a percent (standard deviation of a single measurement) for time constants of 10 seconds or more. Thus, the state-of-the-art uncertainty of spectral irradiance measurements in this UV region is about 3 percent when neither the character of the radiation nor the conditions of measurement contribute significantly to the uncertainty.

A specific case of great interest is the spectral irradiance of the sun at the surface of the earth and at a wavelength of 300 nm. The major additional uncertainty in determining this solar terrestrial spectral irradiance results from the fact that it changes very rapidly with wavelength. At 300 nm, the rate of change is about 5 percent per 0.1 nm. As a result, the best laboratory spectroradiometer would have an additional uncertainty of at least 3 percent due to this factor. Also, this extreme spectral character results in an additional uncertainty of about 5 percent due to the lack of temperature control typical in a field measurement.

Adding all of the uncertainties to the uncertainty of the standard itself and the imprecision of the measurements results in a total estimated uncertainty for a terrestrial solar spectral irradiance determination at 300 nm of 16 percent when using a large laboratory spectroradiometer and 23 percent when using a portable field instrument. The greatest need for reducing the uncertainty of these solar measurements is a spectroradiometer with greater wavelength accuracy and temperature independence.

Better Standards

Significant improvement in laboratory UV measurement, or further improvement in field measurements such as that of the sun, requires more accurate and stable spectral irradiance standards. A factor of three improvement in these standards is considered attainable and NBS is planning a program with

Table 1. **Typical Spectral Irradiances (in μ Wcm^{-2}nm^{-1})**

	280 nm	300 nm	320 nm
Argon Mini-Arc	0.52	0.59	0.65
Argon Maxi-Arc	8.9	10.0	11.0
1000-W Tungsten standard	0.062	0.14	0.28
Terrestrial Solar	0	0.31	26

this as a goal. If this goal is realized, uncertainties for both laboratory and field measurements, assuming adequate spectroradiometers are developed, would typically be a few percent.

Finally, to approach a 1-percent uncertainty in the 250-nm to 350-nm region for which applications are beginning to arise, measurement techniques would have to be developed to reduce the various remaining uncertainties associated with the complex character of the radiation.

Techniques required to achieve state-of-the-art accuracy will be presented in detail in the NBS Self-Study Manual on Optical Radiation Measurements. In particular, a special chapter devoted to UV measurements is planned for later this year. The first chapters of the Manual, now available as NBS Technical Notes 910–1 and 3, discuss concepts of radiation measurements.

Pyroelectric Radiometer

In the Radiometric Physics Group, Jon Geist and colleagues from NBS Boulder and from Laser Precision Corporation have developed an electrically calibrated pyroelectric radiometer. This detector represents a new concept in measuring optical power and may be used to measure the optical power in a wide variety of sources, including the power in a laser beam. The electrical self-calibration makes many radiometric measurements faster and more reliable. Unfortunately, it is not sensitive enough to detect UV radiation from many sources and cannot be used at spectral wavelengths below 160 nm because of the production of secondary electrons at the receiver.

This is a radiometer which is based upon a pyroelectric detector and waveform-independent synchronous amplification. The receiver-heater is alternately exposed to the radiation field and to a calibrating electric current. A phase demodulator is used to provide for null measurements. It has the most accurately known spectral response, better than ±0.5 percent, and has fast response times.

Recent advances in electro-optical technology, particularly the improvement of silicon cell characteristics and the profusion of cw UV and second harmonic laser lines, allow the radiation measurement accuracy of the electrically calibrated detectors to be transferred to the more convenient silicon photodiodes.

Silicon Photodetectors

The Radiometric Physics Section, headed by Dr. J. L. Tech, has constructed a computer-controlled, laser-based characterization facility for use in making detailed studies of silicon photodetectors. The power in the laser beam is measured with the NBS electrically calibrated pyroelectric detector. Then the response to the laser radiation of the silicon detector is measured to study the degradation in performance of some types of these detectors when exposed to UV radiation. Users of these detectors have found this degradation in detector response troublesome.

Dr. Russell A. Schaefer adjusts the optical alignment of computer-controlled, laser-based characterization facility used to make detailed studies of silicon photodetectors.

Two effects have been found to contribute to the degradation. The first, which is common to all silicon detectors measured, is a decrease in the uniformity of response across the surface of the cell as the wavelength of the irradiating beam is shifted to blue and near UV radiation. The second effect, which is present in many silicon detectors, is an enhancement of the detector response after a prolonged exposure to UV radiation. Both of these effects can introduce gross uncertainties in any calibration and seriously impair the utility of any instrument for UV measurement based on such a detector.

The NBS group has found that by carefully controlling the surface preparation during formulation of silicon detectors, it is possible to make silicon photodiodes which do not exhibit enhanced responsivity after exposure to UV radiation.

A system has been designed to transfer the NBS absolute radiant power base in the 250-to 1150-nm wavelength range. The silicon-detector-based radiometer and its accompanying test materials can be used to measure the absolute spectral response of detectors and to provide a diagnosis of some common measurement problems.*

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*The system is described in NBS Technical Note 950.

A series of high accuracy wavelength measurements have been completed for a number of important filters extending down to the UV to 200 nm. Future plans include upgrading the calibrations of the present wavelength standards and offering them as Standard Reference Materials (SRM's).

Summary of Capabilities

A summary of NBS current and projected standard source and detector capabilities is shown in Figure 1. The dashed lines indicate ranges of capabilities expected to be accomplished in the near future. For more details consult "The National Measurement System for Far Ultraviolet Radiometry" by Dr. W. R. Ott.*

Standard sources include hollow cavities designed to closely approximate the ideal blackbody, which is defined as a surface which absorbs all incident radiation and reflects none. The cavity source is designed in the form of an enclosure with a small hole which allows the radiation to be observed. The spectral radiance at this small hole is given by Planck's law and is a function only of the temperature of the enclosure. The advantage of this source is that with the measurement of one parameter, temperature, one has a standard with high accuracy covering a tremendous range of intensity and wavelength. Its limitation in the UV region is that the ultraviolet continuum is extremely weak and practical applications are limited to wavelengths greater than 250 nm.

*Ott, W. R., "The National Measurement System for Far Ultraviolet Radiometry," NBSIR-75-941, 69 pages (June 1977). Available for $4.50 from National Technical Information Service, 5285 Port Royal Rd., Springfield, VA 22151.

Dr. J. Mervin Bridges is shown assembling the argon mini-arc used as a transfer standard for radiance in the 115 nm to 330 nm range.

Synchrotron radiation and radiation from the hydrogen arc source, the argon mini-arc and maxi-arc, the deuterium (D_2) lamp, and tungsten lamps have been discussed. These primary and transfer standard sources emit ultraviolet radiation and are extremely useful in this spectral wavelength region. They are currently being utilized at NBS and at other places nationally and internationally.

Standard Detectors

Standard detectors include ion chambers which are detectors filled with a gas in which each photon absorbed produces an electron-ion pair. This phenomenon produces a current signal which is collected and measured. The most common use of a double ionization chamber as an absolute detector depends on an accurate measurement of the currents to the two identical chambers. This absolute detector is used on the NBS synchrotron source, SURF, to calibrate transfer standard photodiode detectors.

Other primary and transfer standard detectors shown in Figure 1—and the electrically calibrated pyroelectric radiometer and photodiodes, both with and without windows, that have been discussed—are also currently in general use throughout the world as detectors of ultraviolet radiation.

NBS Acting Director Ernest Ambler, in his opening address to the Symposium on Ultraviolet Radiation for Public Safety and Environmental Protection, which appeared in the September issue of DIMENSIONS/NBS, stated that the "current NBS program in UV measurements and standards is comprehensive, covering the region from 4 nm to 400 nm using a variety of standard sources and detectors."

The NBS programs described here provide ultraviolet radiation measurement methodologies and standards to meet the most urgent requirements of industry, the medical community, and the general public. Dr. Ambler described the hazards in our environment caused by increased exposure to ultraviolet radiation and pointed out that there is now a critical need for expanding and improving the nation's UV measurement base. □

ON LINE WITH INDUSTRY

RADIOPHARMACEUTICALS

by David Chaffee

The term radiopharmaceutical may not be as familiar to people as the words polio vaccine or mercurochrome, but that may well change in the coming years. Radiopharmaceuticals are now a $100 million a year industry and they play an important role in the way modern medicine is developing.

A radiopharmaceutical is simply a radioactive substance given to a patient to aid in the diagnosis or treatment of disease. Two examples of radionuclides used in radiopharmaceuticals are technetium-99m (used for a number of imaging studies, including brain, lung, thyroid, bone, kidney and liver) and iodine-131 (used for a number of purposes, including the diagnosis and treatment of thyroid-related disease, localization of brain tumors, and liver studies.)

Recognizing the industry's responsibility for safe and conscientious handling of these products, The Atomic Industrial Forum (AIF) sought the cooperation of the National Bureau of Standards in developing a plan to provide the unbiased measurement technology necessary for quality assurance. This plan was implemented in late 1974 by establishment of an AIF-sponsored Research Associate Program* at the Bureau, with Dr. Ronald Colle serving as the first Research Associate.

Through this cooperative program, AIF and NBS work together to provide maximum confidence in the accuracy of the critical radioactivity measurements involved. As stated in the Memorandum of Agreement between the two groups, "The objectives of this program are to provide Standard Reference Materials and develop techniques for their application to radioactivity measurement assurance in the radiopharmaceutical industry." The present Research Associate, Daniel Golas, replaced Dr. Colle in November of 1976. He is one of some 90 Research Associates who work at NBS in a given year.

"This is the first research program in the world, so far as I know, dealing with the measurement of radiopharmaceuticals in this cooperative way," says Peter de Bruyn, NBS Industrial Liaison Officer. He stresses the importance of measurement accuracy because of the serious problems that can arise if too great or too small an amount of radioactive material is given to a patient.

Golas, aided by NBS scientists and facilities, measures the radioactivity concentration of solution samples. Once accurately characterized, this solution becomes a Standard Reference Material (SRM), duplicates of which then become available. They are sent as blind samples to the AIF participants (and as known samples to any one else wishing to purchase them). The AIF companies then make measurements on the SRM using their own equipment. Agreement between these measurements and the certified radioactivity concentration of the SRM is evidence of the effectiveness of the company's own measurement procedure. If there are discrepancies, corrective actions are taken.

The results of NBS findings and those of the participating companies are normally within five percent of one another, according to Lucy Cavallo, a chemist in the NBS Radioactivity Section, who spends part of her time helping Golas. Occasionally, however, larger variations exist. If there is a substantial difference, it may be necessary for AIF and NBS officials to get together to identify the reason for the difference.

The radionuclides used in SRM's are the ones used in radiopharmaceuticals. Some of the more popular materials, such as iodine-131, molybdenum-99, and xenon-133, are included in SRM distributions every year.

"The trend in industry has been to go to radioactive materials with shorter and shorter half-lives," says Golas. For example, iodine-123, with a 13-hour half life, is finding increasing use in the diagnosis and treatment of various illnesses. This contrasts with the eight-day half life of iodine-131 and 60-day half life of iodine -125 which were used more extensively in the past.

Golas and Cavallo point out that the calibrations NBS makes are based on the requests they get from the radiopharmaceutical manufacturers, evidence of the good working relationship that exists between the two groups. "The Research Associate Program is a clear example of industry and the government working together for the common good," says Calvin Brantley, Chairman of AIF's Committee on Radioisotopes Production and Distribution, and a representative of the New England Nuclear Corporation. This, coupled with strong statements of support from NBS officials, tends to be a good omen for the program's future.

"NBS is in an admirable position to do this work because we have both the personnel and facilities. There is no other independent third body that has both the facilities and the objectivity to do this, and that's why our role is so important," says Wilfrid Mann, NBS Supervisor of the program and Chief of the Radioactivity Section. As radiopharmaceuticals take on an ever-increasing role in modern medicine, the Research Associate Program assumes even greater importance. And, as Mann says only half-jokingly, the program looks as though it will "continue forever."

Chaffee is a DIMENSIONS staff writer.

*The Research Associate Program has brought researchers from all areas of industry to NBS labs for over 50 years to work on projects of mutual interest—for mutual benefit. For information, contact P. R. de Bruyn, Industrial Liaison Officer, Room A402, Administration Building, National Bureau of Standards, Washington, D.C. 20234. Phone: (301) 921-3591.

STAFF REPORTS

PHOTODETECTORS LOSE DYNAMIC RANGE WITH MODULATED SIGNALS

Recent work in the NBS program in time-domain metrology of high-speed optical and electrical pulses has yielded results relevant to fields such as optical and digital communications, computers, radar, control systems, and lasers.

Robert A. Lawton, Room 1–3056, 303/499-1000, ext. 3339; and Matt Young, Room 1–2124M, 303/499–1000, ext. 3223, both of the Electromagnetics Division, Signal Waveform Metrology Section, Boulder, Colo.

We have shown that the high-frequency response of photodetectors may saturate at optical irradiance levels (10 to 1000 watts per square centimeter. W/cm²) well below those required to produce direct current (dc) saturation. Furthermore, a uniform dc responsivity over the face of the detector need not imply the same spatially uniform response to a modulated optical beam. Thus, the dc characteristics are not necessarily reliable indicators of a detector's response to pulsed and modulated optical signals.

The dc and radio-frequency (rf) components of current through silicon photodetectors at each of several irradiance levels were measured simultaneously. From 10 W/cm² to 1000 W/cm² the dc current variation was a linear function of irradiance, but the rf current became nonlinear at 200 W/cm² and decreased above 300 W/cm². Thus, above 200 W/cm² the rf response of the detector becomes progressively less faithful, and we have observed that the pulse-response time becomes longer. This degraded performance would be unexpected on the basis of dc response measurements alone.

The dc and rf characteristics of the photodetectors were obtained with the amplitude-modulated beam from a helium-neon laser of wavelength 633 nanometers. The laser's 30-centimeter tube limits the number of lasing frequencies (modes) to two, with an infrequent third.

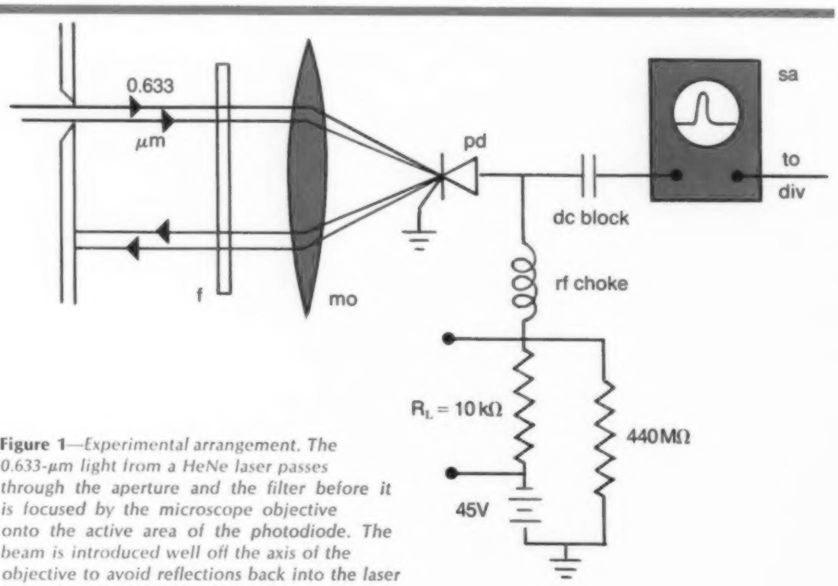

Figure 1—*Experimental arrangement. The 0.633-µm light from a HeNe laser passes through the aperture and the filter before it is focused by the microscope objective onto the active area of the photodiode. The beam is introduced well off the axis of the objective to avoid reflections back into the laser cavity. The photodiode is housed in a microwave bias tee as shown. The rf output of the photodiode is observed with the spectrum analyzer; the dc output is measured as a voltage developed across the load resistor R_L.*

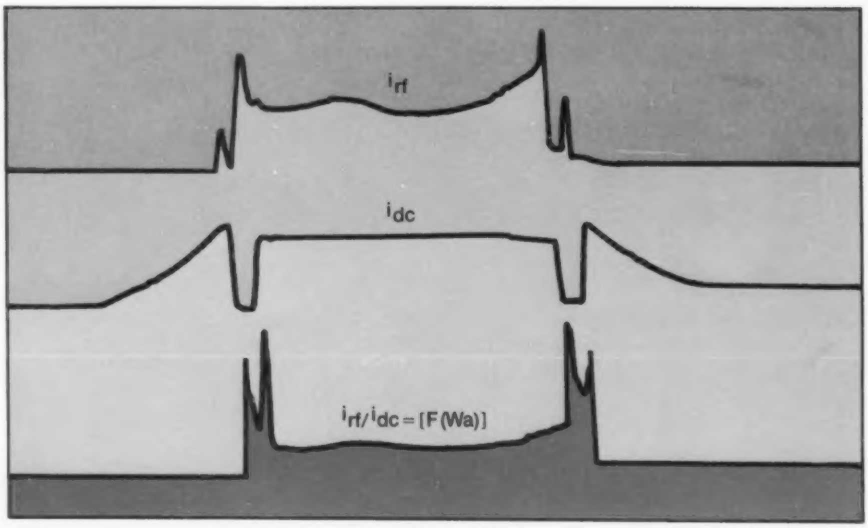

Figure 2—*Scans across a photodetector diameter (D ~ 0.5 mm). Uppermost curve, rf current; middle curve, direct current; lowest curve, frequency response at 600 MHz. Focused beam has diameter of 8 micrometers and average irradiance of 1000 W/cm². The three scans are aligned with each other.*

If the laser is unpolarized, a polarizing filter passes parallel components of the two modes to produce a beam modulated at 600 megahertz (MHz), the intermode beat frequency. Polarized lasers (those with Brewster windows) show intermode beats without a polarizer. Though the two modes may differ in power by as much as 50 percent, both the dc and rf photocurrents remain constant.

In the course of our work, we devised a simple, single-measurement method for estimating a photodetector's frequency response curve. We showed that the value of a detector's frequency response at the intermode beat frequency is equal to the ratio of the rf to dc components of the photocurrent. We were also able to estimate the frequency response function because we found that the impulse response was often approximately a sharp rise followed by an exponential decay.

To look for responsivity variations across the face of the photodetector, we placed the detector in a mount providing three-way movement (along x, y, and z axes). The rf and dc photocurrents and the frequency response (computed by an analog divider) were recorded as the detector moved through the laser focus. Scans along a detector diameter were made at several irradiance levels. The dc response was uniform over most of the detector surface and was linear with irradiance. At irradiances below about 200 W/cm^2, the rf responsivity was also uniform over the detector surface, but saturated and became uneven above 200 W/cm^2. At high irradiance current the rf and frequency responses remained comparatively high only around the edge of the detector face.

These NBS results indicate that researchers in high-speed optical and electronic technology should exercise extreme caution when using photodetectors with modulated or pulsed laser beams.

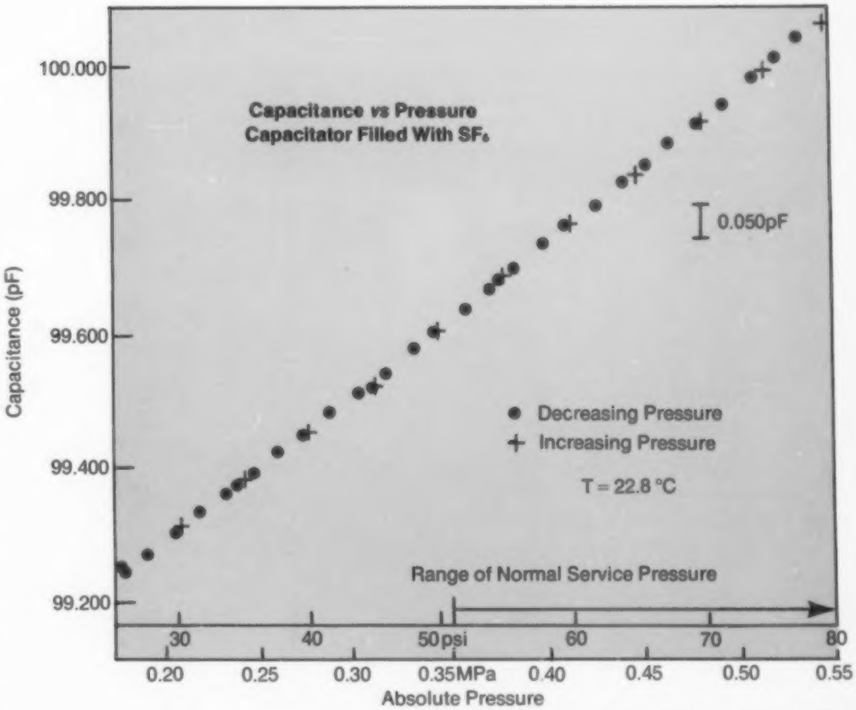

Figure 1—*Pressure dependence of test capacitor.*

AC HIGH VOLTAGE MEASUREMENTS ON FIRMER FOOTING

A cooperative effort between the National Bureau of Standards and the National Research Council (NRC) in Canada confirms that ratios of voltages up to 200 kV at commercial 60 hertz power frequency and, hence, the voltages themselves can be measured to better than 10 ppm uncertainty at both laboratories.

Richard S. Davis, Electricity Division, B344 Metrology Building, 301/921-3121.

The most accurate measurements of high voltage ratios are made with current comparator capacitance bridges in conjunction with stable standard capacitors. To calibrate the ratio of a high voltage metering transformer, for instance, one utilizes such instrumentation. The critical

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Figure 2—*Experimental set up at National Research Council (NRC), Canada. NBS capacitor is at right, NRC capacitor at left and high voltage transformer in background.*

Figure 1—*NBS-developed AC Voltmeter/Calibrator for supporting vibration measurements in the infrasonic frequency range.*

characteristic of a high voltage standard capacitor is its voltage dependence; i.e., the capacitance variation with voltage, which must be accurately known (or, ideally, the capacitance should be voltage independent). Both NBS and NRC have developed standard capacitors that are believed to be independent of voltage up to several hundreds of kilovolts. In the past, the cumbersome nature of these capacitors has made direct intercomparison unattractive.

Recently, however, stable, commercially produced, SF_6-insulated, compressed gas capacitors have become available. These can be energized to 200 kV and transported with little difficulty. Rigorous tests carried on at NBS of one such capacitor indicated that, under controlled conditions, it could serve as a high voltage transfer standard between NBS and NRC.

A cooperative experiment was then carried out. The portable standard was measured against the NBS compressed gas standard using our current comparator bridge at voltages to 200 kV. The portable capacitor was then taken to NRC and analogous measurements made. Finally, the capacitor was returned to NBS where measurements confirmed that no damage had occurred during shipping. Both laboratories agreed on the voltage dependence of the transferred capacitor to within 10 ppm.

While the portable capacitor was at NBS, the effect of SF_6 gas pressure on capacitance was studied. The experimental data clearly show the influence of nonideal gas behavior in SF_6—an indication of the precision of the NBS current comparator bridge.

AC VOLTMETER/CALIBRATOR DEVELOPED

A portable rms digital voltmeter/voltage calibrator has been developed at the National Bureau of Standards to aid vibration testing of equipment purchased by private companies and the Department of Defense. It has a frequency range of 0.1 Hz to 50 Hz with measurement and calibration accuracies of approximately 0.1 percent and 0.02 percent, respectively. The primary applications of the instrument are measuring the outputs of vibration transducers and calibrating other voltmeters.

Howard K. Schoenwetter, Electrical Instruments Division, B156, Metrology Building, 301/921-2727.

A high accuracy rms digital voltmeter (DVM) has been developed to support vibration measurements in the infrasonic frequency range where commercial voltmeters have poor accuracy, or do not function at all, and often have excessively long response times. Since the means for calibrating the voltmeter below 10 Hz did not exist, a voltage calibrator was also developed and incorporated into the same instrument.

The calibrator basically consists of a Kelvin-Varley divider fed by a reference voltage (either dc or sine wave, generated by a read-only-memory—digital-to-analog converter combination). A multijunction thermal converter was selected as the sensing device in the rms/dc converter of the DVM since its low ac/dc difference facilitates calibration of the ac calibrator. Filtering in the rms/dc converter and associated circuits was optimized to effect relatively short response times at the lowest frequencies. The rms DVM can measure voltages from 2 mV to 10 V over the frequency range of 0.1 Hz to 50 Hz with accuracies of 0.1 percent to 0.2 percent of reading. The maximum response time occurs at 0.1 Hz and is 40 seconds (to within 0.05 percent of input change). The calibrator covers the same frequency range for voltages up to 7 VAC and has an accuracy of 0.02 percent + 0.4 μV.

A primary application of the voltmeter is to measure the outputs of vibration transducers while they are being calibrated and when they are used for vibration testing. These transducers (accelerometer-amplifier systems) are used to determine the acceleration of vibration exciters, fixtures, and tables. Vibration testing is required to qualify equipment purchased by DoD and other government agencies, as well as by private companies.

In addition to calibrating the companion DVM, an important application of the ac calibrator is to calibrate other voltmeters, effectively extending their measurement capability at very low frequencies. The calibrator can also be employed to make measurements with accuracies approaching its own accuracy, using the DVM as a transfer voltmeter.

The AC Voltmeter/Calibrator has already been used at the Metrology and Calibration Centers of Redstone Arsenal (Army) and Newark Air Force Base, as well as in the Vibration Section at NBS, to measure vibration transducer outputs and to calibrate other ac voltmeters. The other DoD Metrology Center at Pomona, CA (Navy) also plans to use the instrument. The unit will be used at these metrology centers until a commercial version of it becomes available.

UPCOMING DIMENSIONAL STANDARD AIMED AT NEEDS OF MICROELECTRONICS INDUSTRY

A recent test indicates that an upcoming NBS standard can bring needed agreement to measurements made of critical dimensions in microelectronics.

Dennis A. Swyt, Mechanics Division, A123 Metrology Building, 301/921-2182.

First results of a joint microelectronics industry-National Bureau of Standards test of a new NBS photomask linewidth standard and its allied procedures have vividly demonstrated the existence of gross differences in measurement results by different companies using their regular non-NBS calibration standards and procedures. Measurements of the same critical dimensions (upon which integrated circuit reliability and rejection rates depend) within and among the three first-rate companies differed by nearly three times typical design tolerances (for example, differences of 0.7 μm for a 3-μm linewidth).

The NBS response to this situation, in final stages of execution, is a program to develop a comprehensive scheme with all the essential elements of a proper measurement system. Industrial users are to be provided with a linewidth standard (calibrated to $\pm$ 0.05 μm) and measurement procedures for evaluating as well as calibrating measuring instruments.

Primary NBS calibrations are done on an electron microscope/laser interferometer system with secondary, transfer calibrations on a high-performance photometric optical microscope. The entire scheme rests on extensive analysis of the physical phenomena, the measuring devices, and the nature of the measurement process

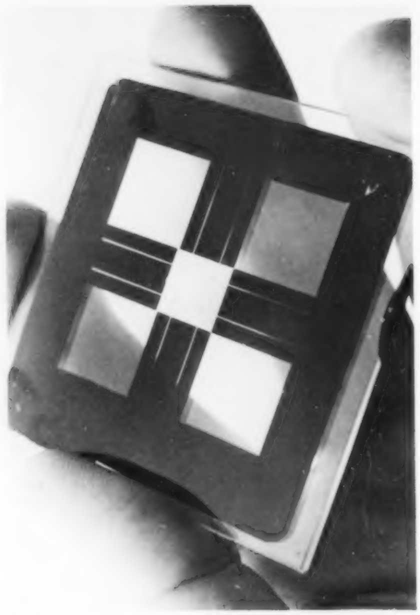

Figure 1—*The NBS photomask linewidth standard, a glass substrate bearing a pattern of lines of deposited chromium, is similar to photomasks used in the manufacture of integrated circuit devices. The widths of certain lines on the standard, when measured by NBS, can be used in the industry to calibrate linewidth-measuring optical or electron microscopes. An early NBS prototype is shown here.*

NEW SRM'S AID INDUSTRIAL HYGIENE ANALYSTS

A new series of Standard Reference Materials developed by the National Bureau of Standards will facilitate more accurate monitoring of a worker's occupational exposure to a variety of organic solvents. The SRM's will help industrial hygiene analysts protect thousands of workers who are employed in industries where exposure to industrial solvents is a daily and potentially hazardous occurrence.

The following newly available Standard Reference Materials provide industrial hygiene chemists with accurate means for calibrating equipment and methods that

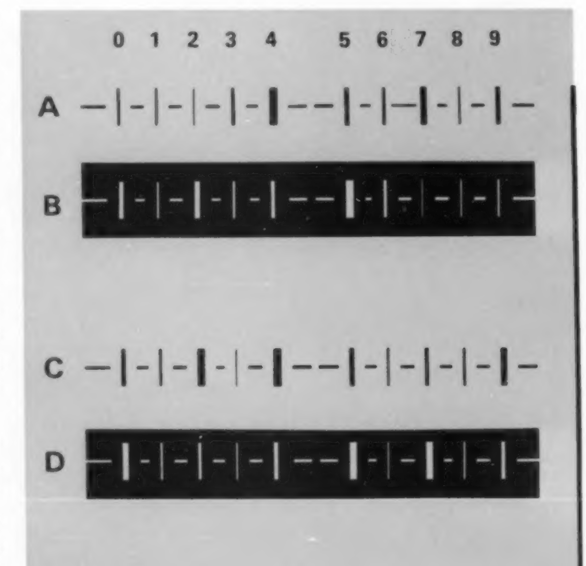

Figure 2—*Among the elements on the new photomask linewidth standard are: opaque lines and clear spaces in calibrated widths from 1 to 10 micrometers (Rows A-D); pairs of lines with calibrated spacings (Row E); and groups of four with calibrated line-to-space ratios (Row F); the standard is designed to evaluate as well as calibrate linewidth-measuring systems. (See Solid State Technology, Jan. 1978).*

are used to determine if workers have been unduly exposed to high atmospheric concentrations of organic solvents in the workplace:

SRM 2661 Benzene on Charcoal
SRM 2662 m-Xylene on Charcoal
SRM 2663 p-Dioxane on Charcoal
SRM 2664 1,2-Dichloroethane on Charcoal
SRM 2665 Chloroform on Charcoal
SRM 2666 Trichloroethylene on Charcoal
SRM 2667 Carbon Tetrachloride on Charcoal

The SRM's are the latest in a series of materials developed in a program jointly sponsored by the National Institute of Occupational Safety and Health and NBS. The purpose of the program is to develop reference materials related to industrial hygiene analysis. Other SRM's developed in the program are:

SRM 2671 Freeze-Dried Urine Certified for Fluoride
SRM 2672 Freeze-Dried Urine Certified for Mercury
SRM 2675 Beryllium on Filter Media
SRM 2676 Metals on Filter Media (lead, cadmium, zinc, and manganese)
SRM 2679 Quartz on Filter Media

The newly available series, SRM 2661-2667, consists of eight tubes, two each of four solvent concentrations. Each SRM costs $87 a unit. SRM's previously issued in the Industrial Hygiene Series cost $82 a unit. They may be ordered from the Office of Standard Reference Materials, Chemistry Building B311, National Bureau of Standards, Washington, D.C. 20234.

RESEARCH MATERIAL NOW AVAILABLE FOR MARINE STUDIES

A new research material for scientists, nutritionists, and environmentalists studying trace elements and hydrocarbons in marine biological tissues is now available from the National Bureau of Standards. The material, designated RM 50, Albacore Tuna, may be purchased from the Office of Standard Reference Materials, Chemistry Building, Room B311, National Bureau of Standards, Washington, D.C. 20234. The price is $59 for two 35-gram cans.

Research Material 50, Albacore Tuna, is freeze-dried tuna fish muscle in which the concentrations of a number of nutritionally and environmentally important substances have been determined. The material was developed by NBS scientists to help satisfy many of the analytical requirements for a base-line marine reference material. The material will also be useful for scientists who are trying to evaluate analytical methods for measuring trace elements in fish and other marine samples. Tuna fish tissue was chosen because it is widely available and is also used as a foodstuff.

The elements which have been measured are mercury, selenium, zinc, arsenic, lead, manganese, sodium, potassium, uranium, thorium, calcium, and strontium. In addition, nine hydrocarbon compounds have been identified.

RM 50 is issued with a Report of Investigation and, unlike an NBS Standard Reference Material (SRM), the data reported are not certified. SRM's are materials whose chemical compositions or particular chemical or physical properties have been accurately determined and certified. SRM's are issued with Certificates of Analysis. In contrast, RM's are accompanied by a Report of Investigation, the sole authority of which is the author of the report. An RM is intended primarily to further scientific or technical research on that particular material.

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CONFERENCES

For general information on NBS conferences, contact Sara Torrence, NBS Office of Information Activities, Washington, D.C. 20234, 301/921-2721.

PRECISION THERMOMETRY SEMINARS

The National Bureau of Standards will sponsor three seminars: Platinum Resistance Thermometry; Liquid-in-Glass Thermometry; and Thermocouple Thermometry. The three seminars will be conducted sequentially. In general, the attendance at each seminar will be kept small in order to establish a close rapport with the attendees during the lecture and laboratory sessions. The material that will be presented will include the definition and discussion of the International Practical Temperature Scale of 1968, methods for realizing values of temperature on the scale, thermometers and instrumentation, and the treatment of calibration data. Time will be scheduled so that attendees will receive exposure to and participate in calibration measurements in the laboratories.

March 13 and 14 and September 11 and 12, 1978, Platinum Resistance Thermometry, Fee $100; March 15 and September 13, 1978, Liquid-in-Glass Thermometry, Fee $30; March 16 and September 14, 1978, Thermocouple Thermometry, Fee $60; March 17 and September 15, 1978, Individual Laboratory and NBS Tour.

For further information contact: Dr. J. F. Schooley, Chief, Temperature Section, A149 Physics Building, 301/921-2801.

CONFERENCE CALENDAR

1978

March 13-14

CONSTRUCTION SPECIFICATION CONFERENCE; NBS, Gaithersburg, MD; sponsored by NBS, the Construction Specifications Institute, and the Guide Specifications Committee of the Federal Construction Council; contact: Roger Rensburger, A151 Technology Building, 301/921-3126.

March 22-24

28TH IEEE VEHICULAR TECHNOLOGY CONFERENCE; Denver, Colo; sponsored by NBS and IEEE; contact: John Shafer, NBS, Boulder, Colo., 303/499-1000, ext. 3185.

April 3-4

8TH ANNUAL CONFERENCE ON EMERGING PATTERNS IN AUTOMATIC IMAGERY PATTERN RECOGNITION; NBS, Gaithersburg, MD; sponsored by NBS and Electronic Industries Association; contact: Russell Kirsch, A317 Administration Building, 301/921-2337.

April 10-13

TRACE ORGANIC ANALYSIS; A NEW FRONTIER IN ANALYTICAL CHEMISTRY, NBS, Gaithersburg, MD; sponsored by NBS; contact: Harry S. Hertz, A105 Chemistry Building, 301/921-2153.

April 17-20

ACOUSTIC EMISSION WORKING GROUP MEETING, NBS, Gaithersburg, MD; sponsored by NBS; contact: John A. Simmons, B118 Materials Building, 301/921-3355.

April 23-26

AMERICAN NUCLEAR SOCIETY TOPICAL CONFERENCE ON COMPUTERS IN ACTIVATION ANALYSIS AND GAMMA RAY SPECTROSCOPY: Mayaguez, Puerto Rico; sponsored by NBS, American Chemical Society, American Nuclear Society, Energy Research and Development Administration, U. of Puerto Rico, Puerto Rico Nuclear Center; contact: B. S. Carpenter, B108 Reactor Building, 301/921-2167.

May 8-10

SYMPOSIUM ON REAL-TIME RADIOGRAPHIC IMAGING, NBS, Gaithersburg, MD; sponsored by NBS and the American Society for Testing and Materials; contact: Donald A. Garrett, A106 Reactor Building, 301/921-3634.

* May 18

TRENDS AND APPLICATIONS 1978: DISTRIBUTED PROCESSING, NBS, Gaithersburg, MD; sponsored by NBS, IEEE Computer Society; contact: Helen M. Wood, B212 Technology Building, 301/921-2601.

* June 12-13

MICROCOMPUTER BASED INSTRUMENTATION, NBS, Gaithersburg, MD; sponsored by NBS, IEEE Computer Society; IEEE Group on Instrumentation and Measurement; contact: John Evans, A130 Technology Building, 301/921-2381.

* June 15

TOOLS FOR IMPROVED COMPUTING IN THE 80's, NBS, Gaithersburg, MD; sponsored by NBS, Washington, D.C. Chapter of the Association for Computing Machinery; contact: Trotter Hardy, A367 Technology Building, 301/921-3491.

June 19-21

GAS KINETICS CONFERENCE, NBS, Gaithersburg, MD.; sponsored by NBS and the Committee on Chemical Kinetics, NBS/NRC; contact: David Garvin, B152 Chemistry Building, 301/921-2771.

June 26-29

CONFERENCE ON PRECISION ELECTROMAGNETIC MEASUREMENTS, Ottawa, Ontario, Canada; sponsored by Institute of Electrical and Electronics Engineers, U.S. National Committee-International Union of Radio Science, and NBS; contact: Dee Belsher, NBS, Boulder, Colo., 303/499-1000, ext. 3981.

July 17-20

AMERICAN ASSOCIATION FOR CRYSTAL GROWTH IV, NBS, Gaithersburg, MD.; sponsored by NBS and AACG; contact: Dr. Robert Parker, B164 Materials Building, 301/921-2961.

*New Listings

NEWS BRIEFS

ATTIC VENTILATION WORKSHOP. The NBS Center for Building Technology will hold a workshop on Summer Attic Ventilation and Whole House Fan Ventilation on July 13, 1978, in Gaithersburg, Md. The purpose of the workshop is to assess summer energy savings achieved by using various types of ventilation equipment. Persons interested in attending should contact Douglas M. Burch, Building Environment Division, National Bureau of Standards, Washington, D.C. 20234, 301/921-3512.

NEW DATA SYSTEM FOR PHASE DIAGRAMS. NBS and the American Society for Metals are cooperating in a major new project to help create a worldwide data system for phase diagrams. The proposed data system will be designed to offer evaluated bibiliographic and numerical data on phase diagrams and on phase characterization for binary and multicomponent alloy systems.

INSULATION TIP FOR WINTER. Do you have insulation in your attic? Even if you do, you may need to add more if you live in a cold climate or if your house is heated by electricity. Don't forget to cover the attic joists completely when adding insulation batts above the level of the ceiling joists. Once the area between them is fully insulated, the greatest heat loss occurs through the joists, which may cover as much as 10 percent of the attic area. This tip and advice on how much insulation to add is available in the NBS consumer guide, <u>Making the Most of Your Energy Dollars</u>. For a copy send 70 cents to Consumer Information Center, Department 184, Pueblo, Colorado 81009.

ONE SMALL LEAP FOR MANKIND. 1977 will be longer than a standard year because the world's timekeepers will add a leap second on December 31. Such additions are made, according to scientists at the National Bureau of Standards, because the extremely accurate atomic clocks used to keep official time gradually get out of step with the earth's rotation, which is erratic. There have been six leap seconds added to the world's time since 1972 when the practice began, according to the NBS. The use of leap seconds is coordinated by the International Time Bureau (BIH) in Paris, France.

PROTOCOL FOR LIBRARY NETWORKS. A set of conventions--or a protocol--has been developed for the content and format of computerized library information. If this protocol is followed, it will be easier to exchange information among library computers. A task force of the National Commission on Libraries and Information Science developed the protocol, with technical assistance from the National Bureau of Standards. It will be used by the Library of Congress, New York public libraries, and other organizations.

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DIMENSIONS/NBS

True or false: The energy you use for home heating can be reduced by up to 50 percent. True, say researchers at the National Bureau of Standards. Read It's Never Too Late To Insulate *in the next issue of DIMENSIONS/NBS.*

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The National Bureau of Standards was established by Congress in 1901 to advance the Nation's science and technology and to promote their effective application for public benefit. Manufacturing, commerce, science, government, and education are principal beneficiaries of NBS work in the fields of scientific research, test method development, and standards writing. DIMENSIONS/NBS describes in technical and general terms results of NBS activity in areas of national concern such as energy conservation, fire safety, computer applications, environmental protection, materials utilization, and consumer product safety and performance. The functions of NBS are divided into four major institutes: Institute for Basic Standards, Institute for Materials Research, Institute for Applied Technology and Institute for Computer Sciences and Technology.

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